R&D Migration: a cross-national analysis

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R&D MIGRATION: A CROSS-NATIONAL ANALISIS

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Abstract

This study contributes to existing literature on firms' innovative activity examining the influence of both internal firms' physical and R&D capital, and external national and international knowledge spillovers. The paper presents a cross national analysis of United States, Japan and Europe based upon a new dataset composed of 879 worldwide R&D-intensive manufacturing firms. The empirical results suggest that the effect of R&D capital stock on firms' innovation output is always positive. The effects of international R&D spillovers are positive in Japan and USA and negative in European economic area, while the national R&D spillovers has the opposite impact.

Keywords: R&D spillovers, Innovation, Cross-national analysis

JEL codes: C23, O33, O4

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1. **Introduction**

Literature considers knowledge and its spillovers an important driver of firms' technological innovation and competitiveness. The benefit of knowledge improves firms' ability to create new knowledge and accrues to other firms by increasing the pool of knowledge that they have access to (Griliches, 1992, 1998; Nadiri, 1993; Coe and Helpman, 1995). Starting from previous studies, we assume that firms' innovative output depends directly on its investment in R&D and physical capital and indirectly on spillovers of innovation realized by other firms. We split these knowledge spillovers in national and international to evidence their nature and relevance. Based on this distinction we realize a cross-national analysis of US, Japanese and European firms' innovative behaviours.

We evidence the linkages between firms' innovations and both their internal and external sources distinguishing between national and international knowledge spillover. Thus, the contribution of this paper to the existing literature is twofold. We assess the importance of national and international spillovers for firms' innovation and we use an international sample to realize a cross-national analysis.

The empirical results lead us to conclude that firms' sensitivity to national and international spillovers differs significantly among three geographic areas. While Japanese and US firms are positive influenced from international spillovers, European firms are more receptive to the national one. The evidence contributes to a better understanding of how national and international spillovers work and has important implications for policy makers and practitioners in US Japan and Europe.

The remainder of the paper proceeds as follows. The next two sections present literature review and theoretical propositions. Section 4 evidences data and empirical methods. Section 5 shows the empirical results. Finally, section 6 and 7 discuss the policy implications and offer some concluding comments as well as some points deserving further research.

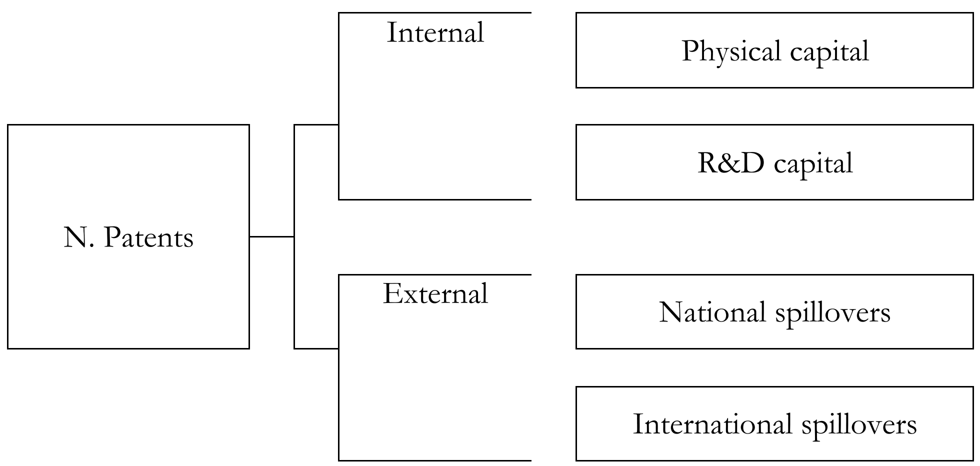
2. **Literature review**

The central role of knowledge for firms' competitiveness has heightened interest in how they might combine their internal R&D efforts with knowledge sourced externally to realize innovation. Firms' innovation depends on both creation of internal knowledge through R&D and physical capital and adoption of external knowledge performed by other firms (Ahuja and Katila, 2001). Since the work by Jaffe et al. (1993) patents have come to be considered to measure both level of firm's innovative output and tacit knowledge flows (Hughes and Wareham, 2010; Liu and Liang, 2003). Specifically, knowledge spillovers have been distinguished in national and international on the base of patent location. Some studies find that patents are more likely to cite other national patents rather than foreign ones (Maurseth and Verspagen, 2002; Jian, 2009; Wang and Chen, 2001). National knowledge spillovers are used to reduce firms' internal investment in physical and R&D capital. In this case, firm is interested in sourcing knowledge more similar to its own upon which the firm then could more readily build (Häussler, 2010, Liu and Chunlin, 2009; Ambos and Ambos, 2011).

Other studies evidence that international spillovers are able to increase innovative productivity (Mei-guang, 2008). These studies identify knowledge flows through cross-country patenting and find that spillovers increase with geographical distance between countries (Coe and Helpman, 1995; Eaton and Kortum, 1996, 1999; Bottazzi and Peri, 2003). In this case, firms may be instead in absorbing international knowledge for improving their technical diversity (Kogut and Chang, 1991; Neven and Siotis, 1996). Specifically, knowledge varies across countries because it depends on location-specific factors such as innovations, education system, linkages between university and firms, innovation systems, intellectual property, trade policies, and agencies promoting R&D (Furman et al. 2002; Denicolai, et al. 2014; Wang and Chen, 2001). Because countries' differences, firms may supplement their internal knowledge and national spillovers with international one (Kuemmerle, 1999; Ahuja and Katila, 2004, Sofka and Grimpe, 2010). Different types of knowledge might be combined advantageously, gives rise to the argument of knowledge sourcing abroad to obtain technical diversity (Cantwell and Janne 1999; Furman et al., 2002; Yang and Hayakawa, 2014).

Analyzing the impact of both national and international spillovers within a knowledge production function framework studies find both positive and negative results on firms' innovative output (Jaffe and Trajtenberg 2002, Maurseth and Verspagen 2002, Peri 2005). Formalizing from prior literature, we estimate the impact on firms innovation of both internal capital and external spillovers (Griliches, 1992; Nadiri, 1993). Specifically, in Figure 1 we summarize our framework evidencing that the firm's innovative output depends on both its internal capital (physical and R&D capital) and external spillovers (national and international spillovers).

Figure 1 Factors affecting firms' innovations



3. **Theoretical framework**

This section will focus on the analysis of the knowledge exchange in the exercise of diffusion of ideas that inventors yield during their innovative process. Following a noteworthy strand of literature (Acemoglu 1996), we consider a simple Non-Overlapping Generation Model where each generation of two different types of agents, both of them normalized to one: people who collect physical capital, defined as entrepreneurs, and those who invest in R&D stated as inventors. All of them, assumed to be risk-neutral and with an inter-temporal preference rate equal to zero, live for two periods. In the first period inventors choose their R&D capital level and entrepreneurs determine the physical capital, in the second one patents, taken obviously as public goods, occur in the form of a partnership of one entrepreneur and one inventor. The benefits from the patents' consumption will be availed at the end of this second period, and then agents die. The patent takes place according to the following functional forms:

$$P_{i,j,t} = AK_{i,t}^{\alpha}K_{j,t}^{RD(1-\alpha)} \quad (1)$$

with: $0 < \alpha < 1$, and where $P_{i,j,t}$ is the patent, $K_{i,t}$ is the physical capital of the *i-th* entrepreneur, and $K_{j,t}^{RD}$ the *R&D* capital of the *j-th* inventor. *A* stands for the technological context and other effects.[1] Furthermore the assumption of randomness as afar as concerns the agents' matching function, will entail that all the inventors (entrepreneurs) have the same probability of meeting each entrepreneur (inventor), and once a partnership has been formed is too costly to break it up in order to find a new partner for each agent. The randomness of the matching function will imply anonymity of contracts, in the sense that each inventor (entrepreneur) does not know the type of the entrepreneur (inventor) she/he is going to meet, and consequently her/his decisions will depend on the whole distribution of physical (*R&D*) capital across all the entrepreneurs (inventors).

The utility functions of the *i-th* entrepreneur and of the *j-th* inventor are given by the following:

$$U_{i,t} = P_{i,j,t}^{e} - \frac{\theta_i K_{i,t}^{(1+\gamma)}}{(1+\gamma)} \quad (2)$$

$$U_{j,t} = P_{i,j,t}^{e} - \frac{\lambda_j K_{i,t}^{RD(1+\gamma)}}{(1+\gamma)} \quad (3),$$

where θ_i (λ_j) is a positive taste parameter which captures the disutility of accumulating physical (*R&D*) capital made in order to obtain patents. Eqs (2) and (3) may be rewritten as follows:

$$U_{i,t} = AK_{i,t}^{\alpha} \int K_{j,t}^{RD(1-\alpha)} dj - \frac{\theta_i K_{i,t}^{(1+\gamma)}}{(1+\gamma)} \quad (4)$$

$$U_{i,t} = AK_{j,t}^{RD(1-\alpha)} \int K_{i,t}^{\alpha} di - \frac{\lambda_j K_{i,t}^{RD(1+\gamma)}}{(1+\gamma)} \quad (5).$$

From the f.o.c.: of the maximization process we may derive:

[1] It is only for simplicity that we don't introduce parameters capturing the technological and geographical proximity.

$$K_{i,t} = \left\{ \frac{A\alpha \int K_{j,t}^{RD(1-\alpha)} dj}{\theta_i} \right\}^{\frac{1}{\gamma+1-\alpha}} \quad (6)$$

$$K_{j,t}^{RD} = \left\{ \frac{A(1-\alpha) \int K_{i,t}^{\alpha} di}{\lambda_j} \right\}^{\frac{1}{\gamma+\alpha}} \quad (7)$$

from inspection of which it follows that the physical (*R&D*) capital will increase with the *R&D* (physical). As result we can state what follows:

Proposition 1: *Assuming* $\theta_i = \theta,\ \lambda_j = \lambda$*:*

1. *There exists a unique equilibrium, Pareto inefficient, given by:* (K^*, K^{RD*}).
2. *There are social increasing returns in the sense that that a small increase in investors' (entrepreneurs') R&D (physical) capital will improve welfare of all agents*;
3. *When a small group of investors (entrepreneurs) invest more in R&D (physical) capital, other agents will respond, and the equilibrium rate of return of all subjects will improve.*

The first two observation of Proposition 1 (proved in Appendix A) states that the equilibrium of this economy is unique, Pareto -inefficient and exhibits social increasing returns *a la Acemoglu* (1996) Furthermore there will be a stronger form of social increasing returns in the sense that when small group of investors decide to make investment in order to increase the number of patents, other agents respond by increasing their investments, and so the rates of returns of investors who have not invested more will improve. In the following empirical analysis, we explore whether technological spillovers, both from national and international competitors, significantly affect the own innovation level, measured by the number of patents.

3.1 *R&D* migration

In what follows we consider an additional source of *R&D* capital accumulation: immigration of investors with a different talent towards *R&D* capital accumulation. We assume two economies, the host and the source with a continuum of agents, living for two periods as before, and normalized to unity.

As regards the behavior of native investors the analysis will follows the previous line of reasoning; on the foreign inventors side the decision related to investment in R&D capital is strictly related to the migration decision. This latter will depend on the comparison between the optimal utility levels derived from moving or otherwise. The utility functions of foreign inventor who decide or not to move may be respectively written as follows:

$$U_{j,t}^{f} = P_{i,j_f j,t}^{e} - \frac{\delta_{j_f} K_{j_f,t}^{fRD(1+\gamma)}}{(1+\gamma)} \quad (8)$$

$$U_{j,t}^{o} = \left\{ P_{i,j_f,t}^{oe} - \frac{\delta_{j_f} K_{j_f,t}^{oRD(1+\gamma)}}{(1+\gamma)} \right\} \phi_{j_f} \quad (9)^{2},$$

where ϕ_{j_f} is a positive taste parameter assumed to be greater than unity to capture the hypothesis of a preference for living in the origin country, different among inventors, and distributed, as in Carillo and Vinci (1999), according to a uniform cumulative distribution function $F(\phi)$ with parameter *b*. Maximizing the above utility functions (eqs.8 and 9) we may easily derive the following:

$$K_{j_f,t}^{fRD} = \left\{ \frac{A(1-\alpha)\int K_{i,t}^{\alpha} di}{\delta_{j_f}} \right\}^{\frac{1}{\gamma+\alpha}} \quad (10)$$

$$K_{j_f,t}^{oRD} = \left\{ \frac{A^{o}(1-\alpha)\int K_{i_f,t}^{\alpha} di_f}{\delta_{j_f}} \right\}^{\frac{1}{\gamma+\alpha}} \quad (11).$$

In order to decide whether to migrate or not, each inventor will compare the two maximum utility levels: U^{f*}, U^{o*}. We will assume that an inventor will move from the source country if and only if:

$$U^{f*} > U^{o*} \quad (12).$$

After simple algebraic substitutions the migration condition decision (12) may be rewritten as follows:

$$\phi_{j_f} < \bar{\phi}\text{, where: } \bar{\phi} = \frac{P_{i,j_f j,t}^{e} - \frac{\delta_{j_f} K^{*fRD(1+\gamma)}}{(1+\gamma)}}{P_{i,j_f,t}^{oe} - \frac{\delta_{j_f} K^{*oRD(1+\gamma)}}{(1+\gamma)}} \quad (13).$$

From inspection of the migration decision condition it may be observed that the number of inventors who decide to migrate will depend on the distribution function of the taste parameter ϕ_{j_f}, on the population, and on the parameters that determine the threshold value $\bar{\phi}$ that depend on economic conditions in both the source and destination country. Finally the share of moving inventors will be:

$$\chi = \int_0^{\bar{\phi}} \frac{1}{b} d\,\phi_{j_f} = \frac{\bar{\phi}}{b} \quad (14).$$

Hence the entire population of inventors, native and immigrant will be: $(1+\chi)$[3]. Normalizing once again to unity the latter expression and labeling with β the percentage of native inventors, the share of foreign inventors in the host country is: $(1-\beta) = \frac{\chi}{1+\chi} = \frac{\bar{\phi}}{b+\bar{\phi}}$.

[2] Where *f* and *o* refers to foreign and origin country.

At this point from the maximization process we obtain:

$$K_{i,t} = \left\{ \frac{A\alpha(1-\beta) \int K_{j_f,t}^{fRD(1-\alpha)} dj_f + \beta \int K_{j,t}^{RD(1-\alpha)}}{\theta_i} \right\}^{\frac{1}{\gamma+1-\alpha}} \quad (15)$$

Proposition 2: *We may distinguish two different cases: a) if foreign inventors' R&D capital is higher than the natives' one there are social increasing returns, and immigration policies of inventors may be considered as a source of investment in R&D; b) in case of investors with a lower level of R&D capital, social increasing returns may be reversed; in any case immigration will reduce the average R&D capital level.*

Proposition 2 is proved in Appendix B.

4. **Methodology**

The dataset is constructed with the view of setting up a representative sample of the largest firms at the international level that reported R&D expenditures. The information on company profiles and financial statements comes from all EU R&D investment scoreboards editions issued every year until 2011 by the JRC-IPTS (scoreboards).

R&D data from the scoreboards represent all R&D financed by the companies, regardless of the geographical localization of R&D activities. Scoreboard data are collected from audited financial accounts and reports[4.] Combining the most recent scoreboard to avoid multiple counting of the same observation, we obtain an unbalanced panel of 22697observations for 3430 firms, for the period 2000-2010. For each firm, information is available for the annual capital expenditures (Cexp), annual R&D expenditures (RD) and main industry sectors according to the Industrial Classification Benchmark (ICB) at the two digits level. OECD, REGPAT database, January 2012[5,6] is the second source of information used in this study. This database covers firms' patent applications to the European Patent Office (EPO) including patents published up to December 2011. The matching procedure follows the same problems as in Aldieri and Vinci (2015).

Each monetary observation is converted into constant currency (in EUR) and prices[7.] It should be noted that data in the R&D scoreboards are already expressed in Euros and that a single scoreboard uses a fixed exchange rate for each currency to convert data into Euros for every periods that it covers.

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[3] Since we are analysing a context with no unmatched agent, we will assume an equal increase of entrepreneurs in destination country.

[4] See Moncada Paternò Castello et al. (2009) for more details.

[5] See Maraut S., H. Dernis, C. Webb, V. Spieazia and D. Guellec (2008) for the methodology used for the construction of REGPAT.

[6] Please contact Helene.DERNIS@oecd.org to download REGPAT database.

[7] Reference year is 2007. Sources for exchange rates and deflators are EUROSTAT.

Thus, first we convert the data into original currencies by using the exchange rates specific to each scoreboard. Second, data in original currencies are converted into Euros using a fixed exchange rate[8]. Using national GDP price deflators with 2007 as the reference year performs transforming data into constant prices[9]. The R&D and physical capital stocks (K and C, respectively) are constructed by using a perpetual inventory method (Griliches, 1992), by considering a depreciation rate of 0.15 for R&D capital stock and 0.08 for physical capital stock, which are usually assumed in the literature. The growth rates that are used for the initial values in this study are the sample average growth rates of R&D and physical capital expenditures in each two-digit Industry Classification Benchmark (ICB) industry.

Once the firms with missing values for some variable of our sample are removed, we get 909 firms over the period 2002-2010. Furthermore, in order to trim the dataset from outliers, the following procedure is implemented. All observations for which the R&D intensity (defined as the R&D investments divided by the firm's net sales) is below 0.1% or above 100% are deleted. This removes 5 firms for the first threshold (mainly firms from the retail and travel and leisure industry sectors) and 25 firms for the second criteria (firms mainly in the pharmaceuticals sector[10]). This leads to an unbalanced panel of 879 firms, as in Aldieri et al. (2014). In this paper, we follow the methodology developed by Jaffe (1986) to compute the technological proximity. Starting from this proximity measure, we consider the national and international spillover stocks (NS and IS) for each economic area (Europe[11], Japan and USA).

The model that is estimated is the following:

$$pi = f\,(Ci\,,\,Ki\,,\,Xnat\,,\,Xint\,) \quad (16)$$

where *pi* is the number of patents of firm i, *C*i is physical capital of firm i, *K*i is R&D capital of firm i, *Xnat* is the national spillover and *Xint* is the international one. In table 1, we indicate the summary statistics of our sample.

Table 1. Main factors affecting innovation

Variable	Mean	Std. Dev.
pi	1.41	2.557
Ci	7.05	1.839
Ki	6.56	1.446
Xnat	11.66	0.801
Xint	12.46	0.486

[8] We use the exchange rates in Eurostat for year 2007.

[9] Eurostat GDP deflators.

[10] These firms are research specialized laboratories whose unique activity is R&D. Sales are very limited and this explains a very high R&D intensity, i. e. above 100%.

[11] Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Spain, Sweden, Switzerland, The Netherlands and the United Kingdom.

Note: 6207 observations.

Since the patent citations are count data and they are not normally distributed, OLS is not opportune (Greene, 1994; Winkelmann and Zimmerman, 1995). For this reason, we implement the Poisson model, as in Aldieri (2011).

5. **Results**

In table 2, we report the results of the analysis for each economic area. We may observe that the effect of own R&D capital stock on the innovation output, the patents, is always positive, as expected. The effects of international R&D spillovers are positive in Japan and USA and negative in European economic area, while the national R&D spillovers has the opposite impact.

This seems to indicate the higher ability of leader countries in innovation environment (Japan and USA) to assimilate outside knowledge and to exploit it in higher innovation output, as the number of patents.

Table 2. Cross-national analysis

	EU firms		JP firms		US firm	
	Est.	s.e.[a]	Est.	s.e.[a]	Est.	s.e.[a]
Ci	- 0.04*	(0.021)	0.08**	(0.039)	0.32***	(0.019)
Ki	0.63***	(0.030)	0.28***	(0.051)	0.18***	(0.025)
Xnat	1.06***	(0.125)	- 0.53***	(0.095)	- 0.62***	(0.150)
Xint	- 0.27**	(0.122)	2.52***	(0.205)	1.44***	(0.152)
Pseudo R^2	0.61		0.61		0.63	

a: *** Coefficient significant at the 1%, ** Coefficient significant at the 5%, * Coefficient significant at the 10%

6. **Policy implications**

Since innovativeness is linked to productivity, and this in turn is vital for economic development, any policy measure supporting it, such as R&D subsidy, R&D tax credit, funding R&D and Science and Technology collaborations could be justifiable. In order to make more efficient the innovation activity, policy makers should consider the relevance of geographic proximity, by attracting and agglomerating R&D companies in a given territory or space. They should consider the relevance of technological proximity through the measure allowing increased concentration in particular industries and technological sectors. Finally, given the role of R&D activities to enhance the absorptive capacity of firms to identify, assimilate and exploit external knowledge, policies promoting this function of R&D, such as R&D subsidies or upgrading the skills of company's research personnel should be stimulated. Thus, in order to allow the information remains a private asset for the source unit, public regulations are to be implemented, because the market cannot ensure this process efficiently. For this reason, on

one hand the intellectual property rights allow the ability of entrepreneurs to temporarily hold on the profitability of their ideas through patents or copyrights, on the other hand, such barriers to entry in the market prevent the exploitation of informational developments by rival firms within an industry.
Furthermore, if the firm's research and development expenditure leads to a social benefit, this is often higher than the private return of the firm's research. In this case, a Government subsidy can be offered to the firm in return for its continued output of that benefit. Even if these subsidies are useful for a more appropriate social equilibrium, they are hated by taxpayers, because they may not directly benefit from the researching firm's subsidized knowledge spillovers.

7. **Conclusions**

Our study shows that national and international spillovers can affect firms innovative ability in many ways. Specifically, our results suggest that the effect of R&D capital stock on firms' innovation output is always positive. The effects of international R&D spillovers are positive in Japan and USA and negative in European economic area, while the national R&D spillovers has the opposite impact.
These results seem to indicate the higher ability of Japanese and American firms to assimilate outside knowledge and to exploit it in higher innovation output. To extend our results, our prescriptions can be compared to firms of emerging countries or Asia, such as China, for evidencing new and interesting results.

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Appendix A (Proof Proposition 1)

1.) By combining eq. (6) and (7) we obtain the equilibrium values:

$$K^{*} = A\left(\frac{\alpha}{\theta}\right)^{\frac{(\alpha+\gamma)}{(\gamma+1)}}\left[\frac{(1-\alpha)}{\lambda}\right]^{\frac{(1-\alpha)}{(\gamma+1)}} \quad \text{(A.1)}$$

$$K^{RD*} = A^{\frac{(\alpha+1)}{(\gamma+\alpha)}}\left(\frac{\alpha}{\theta}\right)^{\frac{\alpha}{(\gamma+1)}}\left[\frac{(1-\alpha)}{\lambda}\right]^{\frac{\gamma+1+\alpha(1-\alpha)}{(\gamma+1)(\gamma+\alpha)}} \quad \text{(A.2)}$$

In order to demonstrate Pareto inefficiency, we may write:

$$U_{i,t}^{*} = AK_t^{*\alpha}K_t^{*RD(1-\alpha)} - \frac{\theta K_t^{*(1+\gamma)}}{(1+\gamma)};$$

hence, considering small changes in the equilibrium values we will have:

$$dU_{i,t}^{*} = dK_t^{*}\left[\frac{A\alpha K_t^{*RD(1-\alpha)}}{K_t^{*(1-\alpha)}} - \theta K_t^{*\gamma}\right] + dK_t^{*RD}\left[\frac{A(1-\alpha)K_t^{*\alpha}}{K_t^{*RD\alpha}}\right] \quad \text{(A.3)},$$

from inspection of which it is clear that the term multiplied by dK_t^{*} is zero, whereas the other one is positive. Similar reasoning may be applied to $dU_{j,t}^{*}$.

2.) From inspection of eqs (6) and (7)

3.) Furthermore, when a small group *m* of inventors experiment a reduction in λ toλ_1 we will have:

$$K^{RD*} = A^{\frac{(\alpha+1)}{(\gamma+\alpha)}}\left(\frac{\alpha}{\theta}\right)^{\frac{\alpha}{(\gamma+1)}}\left[\frac{(1-\alpha)}{\lambda}\right]^{\frac{\gamma+1+\alpha(1-\alpha)}{(\gamma+1)(\gamma+\alpha)}} \quad \text{(A.4)}$$

$$K^{1RD*} = A^{\frac{(\alpha+1)}{(\gamma+\alpha)}}\left(\frac{\alpha}{\theta}\right)^{\frac{\alpha}{(\gamma+1)}}\left[\frac{(1-\alpha)}{\lambda_1}\right]^{\frac{\gamma+1+\alpha(1-\alpha)}{(\gamma+1)(\gamma+\alpha)}} \quad \text{(A.5).}$$

By dividing equation (A.4) by (A.5), and substituting in eq. (A.1) we may write:

$$K_{i,t} = \left\{\frac{A\alpha}{\theta}\right\}^{\frac{1}{(1+\gamma-\alpha)}}\left[mK^{1RD(1-\alpha)} + (1-m)K^{1RD(1-\alpha)}\left(\frac{\lambda_1}{\lambda}\right)^{\frac{(1-\alpha)[\gamma+1+\alpha(1-\alpha)]}{(\gamma+1)(\gamma+\alpha)}}\right]^{\frac{1}{(1+\gamma-\alpha)}} \quad \text{(A.6)}$$

from which $K_{i,t}$ increase in *m*.

Appendix B (Proof Proposition 2)

Evaluating the effects of small changes in $K^{*}, K^{fRD*},, K^{oRD*}$ and β we may write:

$$dU_{i,t}^{*} = dK^{*}\left\{A\alpha K^{*(\alpha-1)}\left[(1-\beta)K^{fRD*(1-\alpha)} + \beta K^{RD*(1-\alpha)}\right] - \theta K^{*\gamma}\right\} + dK^{fRD*}\left\{\frac{A(1-\beta)(1-\alpha)K^{*\alpha}}{K^{fRD*\alpha}}\right\}$$
$$+ dK^{RD*}\left\{\frac{A\beta(1-\alpha)K^{*\alpha}}{K^{RD*\alpha}}\right\} + d\beta\left\{AK^{*\alpha}\left[-K^{fRD*(1-\alpha)} + K^{RD*(1-\alpha)}\right]\right\}$$

with uncertain sign.